# VIII.11 Florida Hydrogen Initiative*

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Contract Number: DE-FC36-04GO14225

Subcontractors:
- EnerFuels, Inc., West Palm Beach, FL
- Florida Solar Energy Center, Cocoa, FL
- Orlando Science Center, Orlando, FL

Project Partner:
Chevron Technology Ventures LLC, Houston, TX

Project Start Date: October 1, 2004
Project End Date: November 15, 2010

*Congressionally directed project

## Objectives

Develop Florida's hydrogen and fuel cell infrastructure by:

- Creating partnerships for applied technology demonstration projects throughout the state.
- Sponsoring research and development in the production, storage and use of hydrogen and in the use and application of fuel cells.
- Facilitating technology transfer between the public and private sectors to create, building and strengthen high-growth potential, high technology companies.
- Developing industry support or potential for widespread applications.
- Developing unique hydrogen/fuel cell university level education programs.

## Technical Barriers

This project addresses the following technical barriers from the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

From the Fuel Cell section:

(C) Performance
(E) System Thermal and Water Management
(G) Start-up and Shut-down Time and Energy/Transient Operation

From the Education section:

(A) Lack of Readily Available, Objective, and Technically Accurate Information
(B) Mixed Messages
(E) Regional Differences

From the Technical Validation section:

(C) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

## Contribution to Achievement of DOE Technology Validation Milestones

This project will contribute to achievement of the following DOE milestones from the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 11 (Education): Develop set of introductory materials suitable for a non-technical audience. (4Q, 2006)
- Milestone 24 (Technology Validation): Validate a hydrogen cost of $3.00/gge (based on volume production). (4Q, 2009)

## Accomplishments

- Project has solicited proposals to conduct research, development and demonstrative work.
- Initially selected four projects – October 2004 to October 2007.
- New program management in October 2009.
- Solicited new projects in October 2009.
- Selected three new projects in January 2010. Received DOE approval.
- Solicited additional new projects by issuing request for proposals in April 2010.
- Preliminary selection of five additional new projects made in May 2010.

## Introduction

The contract for operation and management of the Florida Hydrogen Initiative (FHI) project was transferred from the FHI, a not-for-profit corporation, to the University of Central Florida (UCF) in October 2009. UCF's Office of Research and Commercialization and UCF's Finance and Accounting Division manages the contractual and financial aspects of the project and the issuance of subcontracts, per established procedures. Ms. Ashuantay Houston is in charge of the contractual and financial aspects of the project. Project management and technical oversight is provided by UCF's principal investigator, Dr. David Block of UCF's Florida Solar Energy Center (FSEC).

## Approach

Following the change in operation and management of FHI, the project managers began the process of allocating the remaining funds (~$2.5 million) to new projects and finishing and/or completing old projects. Each of the FHI sub-project activities are designated as a Task number within the project. At the present time, there are nine tasks. The first six tasks are old projects. Tasks 1, 3, 4, 5 and 6 are now completed. Task 2 is continuing and Tasks 7, 8, and 9 are new tasks. The active tasks, including the two completed this year, are as follows:

- Task 2. Hydrogen Technology (HyTech) Rest Area: Demonstration of a Multi-kW Integrated Methanol Fuel Cell Power Plant for a Highway Rest Area, EnerFuel, Inc. - project continuing.
- Task 3. Assessment of Public Understanding of the Hydrogen Economy through Science Center Exhibits, Hydrogen Exhibit, Orlando Science Center. This project is complete and final report submitted.
- Task 5. On-Site Reformation of Diesel Fuel for Hydrogen Fueling Station Applications, FSEC/UCF and Chevron Technology Ventures. The project is complete and a final report written.
- Task 7. Chemochromatic Hydrogen Leak Detectors for Safety Monitoring, FSEC. New project.
- Task 8. Development of High Efficiency Low Cost Electrocatalysts for Hydrogen Production and PEM Fuel Cell Applications, FSEC. New project.
- Task 9. Understanding Mechanical and Chemical Durability of Fuel Cell Membrane Electrode Assemblies, FSEC. New project.

## Individual Project Descriptions

As stated above, FHI has funded individual projects which conduct the research, development and demonstration activities. Each of the individual projects are approved by DOE before work can begin. During the past year, one project was a continuing effort, two were completed, three new projects were approved and a request for proposal was issued. With this background, each of the six past year projects are described in the following sections.

### Task 2. Hydrogen Technology Rest Area: Demonstration of a Multi-kW Integrated Methanol Fuel Cell Power Plant for Highway Rest Area

The only active old task is Task 2 being done by Michael Fuchs of EnerFuel, Inc., 561-868-6720, x239. The project activities conducted in the past year are:

- Examined three new demonstration sites. Selected and received approval for a demonstration site of an electric vehicle charging station at Florida Atlantic University (FAU) in Boca Raton, FL. Secured the support of FAU to design, construct and evaluate the charging station and developed required documentation for DOE approval.
- New site activities include designing charging station using existing fuel cells and inverters and secured all permits necessary to begin construction phase and successfully incorporated the existing inverter/fuel cell systems into the design of the charge station.
- Future actions are to construct fuel cell demonstration site, operate charge station for period of three months, determine overall electrical efficiency, document system transient response to load changes, and determine overall performance and effectiveness of charging station.

### Task 3. Assessment of Public Understanding of the Hydrogen Economy through Science Center Exhibits, Orlando Science Center, FL.

The H2Now exhibit has completed software and hardware 'shakedown' that resulted in a streamlined interface and communication and is functioning at 100% in the Orlando Science Center (OSC). The exhibit is so popular that exit intercept surveys that OSC regularly conducts have revealed that visitors like the exhibit and wish that there was more to it. In response, OSC has added a video presentation produced by the H2Now exhibit designers, IDEAS, Inc., titled "I Am Hydrogen" and developed a panel exhibit on other alternative energy resources. Future plans for H2Now include developing an interactive instructional video game based on hydrogen and other renewable energy sources. The video game was developed using a grant from Progress Energy Foundation. OSC has submitted its final report "Summative Evaluation Findings H2Now: (submitted with the 2009-01 Quarterly Report to DOE).

The learning objectives established for H2Now were established so that after participating in the exhibit, visitors would be able to:

- Explain what hydrogen is, where it comes from, and some of its possible uses.
- Distinguish between truth and myth about hydrogen as an alternative energy source, and give specific examples.
- State a benefit and a challenge of hydrogen as an alternative energy source.
- Give an example of how hydrogen power is created, and how it can affect everyday life.
- Comment on a possible impact of hydrogen power on the future state of the world.

Evaluations to determine the extent to which H2Now meets educational objectives revealed that:

- 77% of the visitors surveyed either loved or liked the exhibit.
- 64% indicated that they 'learned something' or found the exhibit 'informative' in the word choice section of the interview.
- 32% found the exhibit 'interesting' indicating that both cognitive and affective learning has clearly taken place.
- 65% indicated that they found out something they didn't know before. This finding is a clear indication of both cognitive gain and a change of attitude, i.e., compare this to the 44% who, when given the choice to select "I learned something new".

**Task 6. On-site Reformation of Diesel Fuel for Hydrogen Fueling Station Applications**

This project was conducted by N.Z. Muradov, A. T-Raissi, C. Linkous, K.K. Ramasamy, C. Huang, and F. Smith of the Florida Solar Energy Center, jointly with the Chevron Technology Ventures, LLC, Dr. James Stevens, Technical Advisor. The project was started in January 2008 and was completed in January 2010. The final report was submitted to DOE in April 2010.

The objective of the project was to develop a new on-demand forecourt hydrogen production technology by catalytically converting high-sulfur hydrocarbon fuels to an essentially sulfur-free gas. The removal of sulfur from reformate is critical since most catalysts used for the steam reformation have limited sulfur tolerance. The FSEC's responsibilities included building, operating and validating the performance of a diesel pre-reformer as well as developing and demonstrating a small-scale desulfurization unit. Chevron Technology Ventures provided catalysts and know-how for the design and fabrication of the pre-reforming reactor. The pre-reformer was coupled with a regenerable $Fe2^{+}/Fe3^{+}$ redox/electrolysis system used for hydrogen sulfite removal from the pre-reformer effluent.

Results from laboratory tests showed that electrolysis of acidic $FeSO_4$ aqueous solution was highly efficient with a coulumbic efficiency of 100% at a cell potential of 1.0 V and that the electrolytic process can be made to operate with a Pt-free anode to oxidize ferrous to ferric ions, thereby reducing the cost of the electrolytic scrubber. FSEC researchers have also developed a robust bi-functional catalyst for accomplishing the pre-reformation of the high-sulfur fuels (sulfur content as high as 5,240 ppmw) to short chain hydrocarbons (C1-C4, mostly propane) at an average yield of about 97%. Furthermore, results showed that after100 hours of continuous operation, the combined $Fe2^{+}/Fe3^{+}$ redox/electrolyzer $H_2S$ scrubber and pre-reformer could achieve desulfurization efficiencies greater than 95% and removed sulfur down to less than 5 ppmv in the pre-reformer effluent. The project results were the development of a novel process for converting high-sulfur diesel to a mixture of light molecular weight hydrocarbons that can be readily reformed with steam to fuel cell grade hydrogen gas.

## New Projects Approved during Past Year

Beginning in October 2009 and ending in February 2010, a request for letters of interest (LOI) was issued to select three new projects for submission to DOE. The LOI request resulted in five proposal submittals that were evaluated by a proposal evaluation team of six technical experts.

The results of the evaluation team and discussions on each project's merit with DOE resulted in selection of the following three new projects:

**Task 7.** Chemochromic Hydrogen Leak Detectors for Safety Monitoring – Dr. N. Mohajeri and Dr. N. Muradov, FSEC. The aim of this project is to develop and demonstrate a cost-effective, high specific chemochromic (visual) hydrogen leak detector for safety monitoring at any facility engaged in handling and use of hydrogen. The work will lead to a new generation of versatile chemochromic hydrogen detectors that employ "smart" materials that cost less, possess fast discoloration kinetics, are user-friendly, are reliable and have superior field worthiness.

**Task 8.** Development of High-Efficiency, Low-Cost Electrocatalysts for Hydrogen Production and Proton Exchange Membrane (PEM) Fuel Cell Applications – Dr. C. Huang, FSEC. The objectives of this project are to develop highly active metal alloys with low Pt loading and metal-metal oxide-based electrocatalysts having nanosized grains. The project will conduct research and development for enhanced hydrogen evolution at low cost. The new catalysts will be evaluated for their activity toward hydrogen evolution via electrolysis of water as well as applications for PEM fuel cells.

**Task 9.** Understanding Mechanical and Chemical Durability of Fuel Cell Membrane Electrode Assemblies – Dr. D. Slattery, FSEC. The objective of this project

is to increase the knowledge base of the degradation mechanisms for membranes used in PEM fuel cells. Approaches to mitigate membrane degradation can be classified into three areas: membrane composition changes; radical quenching; and platinum band formation mitigation.

## Issuing of RFP for Final Projects

The final activity of the year was the release of a request for proposals (RFP) for the remaining funds of $1,427,910. The RFP was released on March 17, 2010 with applications due by April 23, 2010. The RFP e-mail stated that FHI had about $1.5 million in funds that are to be awarded in competitive solicited projects and the RFP was sent to a large number of potential responders. Following the receipt of 19 proposals, a six-member review committee was established. The review committee met in May 2010 and a recommendation for the funding of five new projects has been submitted to DOE. Final DOE documentation material is now being developed.

## Conclusions and Future Directions

The FHI project results have produced a stabilized project management, the completion of two projects, the continuation of one project, the awarding of three new projects and the preliminary selection of five additional new projects. At this time, the funding should be totally allocated. The future work will continue the monitoring and conducting of the eight new projects. There are no open issues.

## Patents Issued

**1.** "Method and System for Hydrogen Sulfide Removal," Huang, C., Smith, F., Linkous, C., Ramasamy, K., Muradov, N., T-Raissi, A. U.S. Provisional Patent, No. 61/023,755; July 30, 2009.

## FY 2010 Publications/Presentations

**1.** T-Raissi, A., Muradov, N., Ramasamy, K., Huang, C., & Smith, F. (2010, April 22). "On-site Reformation of Diesel Fuel for Hydrogen Fueling Station Application", Final report for Department of Energy, Florida Hydrogen Initiative.

**2.** Muradov, N., Ramasamy, K., Huang, C., Smith, F., Linkous, C., T-Raissi, A., & Stevens, J. "Catalytic Processing of High-Sulfur Diesel Fuel for Stationary Applications", proceedings of *XVIII World Hydrogen Energy Conference*, Essen, Germany, May 2010.

**3.** Muradov, N., Ramasamy, K., Huang, C., Adebiyi, I., Smith, F., Linkous, C., T-Raissi, A. & Stevens, J. "Pre-reforming of High-Sulfur Diesel Fuel for Hydrogen Fueling Station Applications", *Fuel, 89, 1221-1229* (2010).

**4.** Newman, J., & Hunter, K.. (2010, February 18). "Assessment of Public Understanding of the Hydrogen Economy Through Science", Final report for Department of Energy, Florida Hydrogen Initiative.